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ABSTRACT

In a speech given at the National Science Teachers Association meeting in 1972, certain errors found in Junior High School Physics textbooks were identified. The reasons which had been given for these errors included the belief that the explanations given were more readily understood by the students. The need to identify these apparently obvious and intentional misstatements of physics concepts is given as a challenge to teachers of this material. (TS)

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Junior High School: Attitudes, Perceptions, Concepts

Section G

Accuracy and/or Teachability of Texts

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It is rather surprising that one finds so many errors and misleading statements in school books on science. After all, most of this material is well established scientifically and is usually taught correctly in the science departments in colleges, but perhaps not in science education departments. Relatively the greatest concentration of errors seems to be in books at about the Junior High School level, but there is a great deal at other levels also.

There are, of course, typographical errors and similar slips in preparing diagrams. One would hope that these are soon corrected in revised editions.

Then there are intentional cases of misleading and wrong presentations. This is done supposedly in the interest of keeping things simple. Many authors believe in this principle and are willing to excuse almost anything with this general argument. I believe it is usually a rationalization to avoid the effort to present it correctly or even the effort to learn it correctly so that one can present it correctly. It becomes a cliché that is unthinkingly applied to defend almost any poor writing.

A book salesman at the exhibits at the NSTA convention last year told me "but the book is for slow learners" when I asked why errors like the following are published in science books:

> Sketch of alpha particles attracted to the N-pole of a magnet instead of being deflected sidewise in a magnetic field. [1)]

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Is it really defensible to present the effect of a magnetic field on moving charged particles incorrectly in the name of simplification? I can't believe it. The correct way is not that much more difficult or incomprehensible. This experience last year was perhaps the last straw that convinced me to speak at an NSTA convention in an attempt to make some of the people attending aware of the fact that the teaching material that is thrust upon you at this convention or by your school system is not necessarily good.

There are innumerable other examples; I will select a few. Most of these are not valid simplifications in my estimation and I would like to hear from you if you can defend them.

1 kg x 2.2 = 2.2 lb. Should it not be

1 kg x 2.2 lb/kg = 2.2 lb

or similar conversions

1 ft x 12 = 12 in instead of 1 ft x 12 in/ft = 12 in 2)

This type of conversion equation has been defended by the editor. But is it not a disservice to the student to confuse him as to the meaning of an equation in mathematics? I have to admit it is simpler, but it is nonsense. It says 12 ft = 12 in. Isn't science teaching one of the opportunities to let the student see logic at work, to see mathematics at work? Even the slow learner should be shocked and mistrust his instructor and text. I can't believe that this sort of thing can really be defended as necessary simplification. Put it in words and say "we get the number of inches by multiplying the number of feet by twelve," but don't pretend the mathematical expression is valid.

For variety let us look at a college book. I know the author knows better. He has written excellent advanced college books.

Picture of card flipped from under a coin with the statement:

"The coin exhibits inertia in its reluctance to move unless acted on by a force. If one tries to give it too great an acceleration, the corresponding force is greater than the friction holding the coin on the card, and the coin suffers no horizontal acceleration at all." 3)

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Does the author really think this is a necessary or valid simplification? Everyone knows that the frictional force is independent of the velocity. Why contradict this statement when the phenomenon is so easily analyzed by stating that when the force is acting for a short time the velocity (acceleration times time) acquired is small.

I have found this same experiment discussed in similarily wrong terms in the Association's journal Science and Children. So you can't hope that your students get the wrong information only in college. They get it very early, either straight in their own books or by being taught by misinformed teachers. The AAAS program Science - A Process Approach has a teacher commentary that among many other wrong things tells the teacher who needs help

> "If (you are standing on a scale in an elevator and) the elevator descends fast enough, the scale will indicate that you have zero weight." [4)]

The speed of the elevator, of course, is immaterial. The important quantity is the acceleration. Any speed can be obtained if the acceleration acts long enough. It may appear simpler, but it is meaningless. How can the teacher and the student begin to understand their science if the phenomena are presented so incorrectly? Isn't one of the values of science teaching that it is an intellectual activity, that one can and should learn to reason? Some people hope for transfer of the reasoning learned in science classes to other areas of study and activity. But can one learn reasoning from such examples? Of course, there is no transfer possible if science instruction consists of memorizing meaningless phrases.

Some who are in a defensive mood will claim that this is a slip, and the authors were careless and didn't mean what they said. Let us hope so, but it is peculiar that this wrong argument is used several times even in different context, indicating that the authors intended it that way. But I consider it inadmissible as a valid oversimplification, very doubtful at the

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level of the children, but certainly not admissible in the teacher commentary without any explanation or excuses.

Let us look at a few other cases of faulty reasoning.

> Slide showing springs representing the binding of molecules in a solid. At higher temperature the springs have fewer number of turns. "Greater movement (sic) or vibration would cause the imaginary springs to stretch"..."Does this (kinetic) model explain the expansion of liquid water when heated"? 5)

Although the present way of writing textbooks with the inquiry approach in mind seldom provides the answer, one is led to believe the intended answer to the last question is "yes."

This is, of course, peculiar since we know that water contracts when heated from $0^{\circ}C$ to $4^{\circ}C$. So there is no general answer. But maybe we should give the authors the benefit that they wanted to stimulate student discussion and maybe the teachers know enough to tell the students that this model as presented is not adequate.

Let us look at the more fundamental misleading statement. Why should greater movement (whatever that is) result in stretching of the springs? What do students or teachers know about springs? What do you know about springs? The only springs discussed are the ones that follow Hooke's Law; spring balances, etc. where the stretch is proportional to the force, it is usually symmetrical for stretching and compression. If there is greater amplitude, the average spacing is the same. Using this basis, what the reader can be expected to know about springs, this is an incorrect argument to explain expansion. Why pretend that this is an argument? The student will perhaps repeat it and even believe it. But isn't he supposed to reason, to understand it?

The explanation requires an additional step. An asymmetrical spring, where the molecules cannot easily move closer but can move farther apart. In that case the average spacing will increase with more oscillatory energy.

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Demonstrate a spring which is vibrating with such large amplitude that turns touch on compression.

When I mentioned typographical errors equivalent in diagrams, I had peculiar things like this picture in mind where the increased movement of the springs is illustrated by a reduction of the number of turns. At least I can't see any significance to this peculiar change of the diagrams.

At least in some of these cases I can see what I would call misguided attempts at simplification. In all simplifications one can be accused of doing it wrong. I, for example, like the Bohr Model of the atom - it is so obviously incomplete with its plane orbits that I am always amazed about the fact that so many conclusions can be drawn. But what is gained by embellishing it with additional properties which do not lead to useful conclusions? Often we are told that the electrons are concentrated in shells.

(The electron)"travels at such a high speed that it seems to form a solid shell around the nucleus. Imagine that the shell is a tennis ball" ... Helium..."there are now two peas rolling around on the surface." [6a]

This is later called an "energy shell." [6b]

A diagram shows the same misconception in another book.[7]

All these pictures are incorrect. A more correct description if one wants to represent the spatial distribution is shown with the highest probability at the center.

Cloud with concentration near center for the "K-shell"

The first electron in second shell as in Lithium also has the highest probability near the nucleus.

This rubber balloon model is further modified in an article in Science and Children[8] by stating that the orientation of the orbits in an atom

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changes in an arbitrary way and represents "paths that are relatively easy to travel." Whatever that statement is supposed to convey. These additions to the orbit model which do not add anything that more complicated theories tell us seem to be an unnecessary complication. They do not make the model simpler; they do not add anything useful.

Let me return to a few examples of what seems faulty reasoning perhaps with the intent to simplify:

> "Hot particles (Sic)(of a gas) are moving faster; thus in the same period of time they can move farther than colder particles and take up more space" 9)

Is this a reasonable answer to the question whether "a theory that attributes motion to gas particles (can) explain the expansion of a gas with heating"? What is the logic of the argument? If the gas is in a container, the increased speed does not cause expansion. Does this misleading statement make understanding easier? Why not use a meaningful argument that the faster moving molecules will hit the surrounding molecules or the piston in a confining vessel with more force and more often and push them away.

Another example of very strange reasoning: Can anyone give us the reason why a textbook adds the thrust of the various stages of a multistage rocket?

> "Saturn V's first stage cluster delivers 7,500,00 pounds of thrust. The second-stage cluster builds up 1,000,000 pounds of thrust. The third-stage cluster adds another 200,000 pounds. Saturn V has a total thrust of almost 9,000,000 pounds." 10)

What is the meaning of adding the thrust of the various stages? The rockets are burning in succession, and the small thrust of the latter stages is acting on a small vehicle at a later time, and adding this thrust to the thrust of the first stage is insignificant anyway. Does it convey any meaningful information? It seems to lead only to confusion and misconceptions.

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So far we have looked at examples describing physical situations, but there are many cases where there is a peculiar attempt at introducing simple terminology with what seems to me detrimental effects:

> "Heat can be interpreted as the rate of motion" 9)
>
> (speed? energy? temperature?)
>
> Is this time rate . . . i.e. speed?
>
> Is this space rate, i.e. a slope
>
> Heat is a poor term and should be internal energy, but that is an energy and not a rate.

Although a more theoretically inclined physicist will not even admit this; the closest one can come is that temperature is related to the speed.

Even simple mathematical terms are thoroughly confused in physical science books.

> "At the launching pad our rocket weighs 12,000 tons . . . It rises to a height of 4,000 miles. At this height, it has doubled its distance from the center of the earth. At a height of 4,000 miles the rocket weighs only 3,000 tons. Its distance increases. Its weight decreased at the same rate." "The rocket doubled its distance from the center of the earth. Thus its rate of increase in distance is 2" . . . "With this doubling of distance the weight of the rocket decreased in inverse proportion. The inverse proportion is 1/4" 11)

No wonder students have no understanding of such simple terms as rate, proportion, inverse proportion. Should a science course or text not help in getting the habit of consistent terminology? How can we hope to teach scientific literacy if we don't even use the words in a meaningful way. Does this misuse of the terms make it any easier to comprehend the science? Maybe the poets take pride in the flexibility

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and changing nature of language. In science I believe we should strive for unambiguous clear expressions. Any language can best be learned by practice in observing and using; lets give our students a chance to learn the language of science.

You may have noticed that this example is not only peculiar in its terminology but also in confusing the physics. To choose as example for the constancy of mass a rocket that ascends from the earth to a height equal to the earth's radius is rather misleading. Rockets are known to expell propellant and therefore lose mass also.

A few more examples of confusing terminology:

> "The force of a magnet extends out from a magnet in lines or in paths" [12]
>
> (What does that mean?)

> "Sun is a great heat engine" [13]
>
> (Would not furnace be better?)

Heat engines are usually devices that convert heat to mechanical energy.

> "The atomic weights which appear in the Periodic Table of the Elements are the weights of the most abundant isotopes" And accompanying chart showing, for example, C-12.0115 (Cl-35.463) [14]

How can the student believe that carbon-12 defines the unit of atomic weights? Would one not expect that such common concepts as atomic weights can be correctly presented in a 5th grade book? Is anything gained by simplifying in such a misleading way?

> "What does the splitting of an atom set off if the reaction is not controlled?"
>
> Answer: "Chain Reaction" [15]

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Are these examples of material that is easier to teach when it is presented in this misleading or incorrect way?

I can't help but think that most of this kind of presentation is due to extreme carelessness or incompetence.

Many of these things appear repeatedly in successive editions of the same book or in new books by the same author.

Doesn't anybody tell them?

I have found that some editors and authors apparently do not care. I have offered to submit lists of errors --- of which today's selection are examples --- but have not heard from them or I had polite answers "we will call you."

I would urge you as teachers and science education supervisors to tell your school board that such books should not be bought, or that errata sheets should be prepared so that such nonsense is not propagated from one generation to the next.

Since this material is in all your libraries and many of your classrooms, some science supervisors take a peculiar defensive attitude when I point out these errors.

They claim it cannot be so bad because well known consultants are listed on the title page.

Have we not learned from TV that comercials are a business matter and not valid testimonials?

They claim new editions always have errors. That is true, but not necessary in such numbers. But if you don't tell the editors that you expect improved books and tell them the errors you would like to see changed, no changes will be made in new editions. Many of the errors pointed out here today are not from new books but from books which are essentially new editions of old books.

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One last comment: How come students let you and textbooks get away with this sort of thing? At least it is my impression that they do, because I find so much surprise when I point out these things that it appears that the corrections of such erroneous material is not an everyday classroom experience. Are we still teaching science by memorising where the student is expected to accept anything without attempt to make it meaningful? This material just doesn't make sense. Are you successful in making the students believe that this material is right? Is the absurdity of this material one of the reasons why students dislike science? Is their attitude: It doesn't make sense, why bother, and memorise it for the teacher?

Of course, in many cases the teachers can correct the nonsense of the teaching material. But I am afraid not many feel competent to contradict the textbook even if they have their suspicions. But it is up to you to insist on better material if you want to teach science and not just words.

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